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RESEARCH ON ACTIVE TEMPERATURE CONTROL AT GODDARD SPACE FLIGHT CENTER

by

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I. Design Philosophy of Goddard Space Flight Center In-House Satellites

The thermal design philosophy at Goddard Space Flight Center for in-house satellites has been to achieve temperature control primarily by passive means. This method has been successfully applied to spin-stabilized satellites operating under the following ground rules:

(1) For near earth satellites, where it is generally necessary to design for conditions of 60% to 100% sunlight, the structures have been restricted to nearly spherical configurations to minimize changes in absorbed sunlight with sun-spin axis angle.

(2) When highly non-spherical structures have been required, the orbits have been highly elliptical, so that the design could be based on absorption of continuous sunlight varying in magnitude only with changes in the attitude of the spin axis relative to the sun.

(3) Internal power dissipation has either been negligible compared to the total absorbed and radiated power or it has been possible to design on the basis that the power is dissipated at a constant rate.

(4) For design purposes, shadow periods have been assumed to be limited to approximately one hour or less. It has not been necessary to maintain temperature limits for longer shadow periods although 2-1/2 and 9-hour shadows have occurred on Explorers 14 and 18, respectively.

(5) It has been possible for highly elliptical orbits to control the launch time in order to restrict the range of possible sun-spin axis angles or delay for many months the occurrence of long term shadows.

(6) Most of the electronic components and experiments have been designed and tested to withstand a relatively broad temperature range.

II. Need for Active Temperature Control on Future Goddard Satellites

If restrictions on configuration, orbit, launch window, and shadow periods are lifted, it is not possible to control temperatures passively within the limits of approximately -10°C and +50°C. With increasing emphasis being placed on reliability, some device such as an active controller must be employed to keep temperature excursions to a minimum.

III. Characteristics of Existing Active Control Systems

A. Louvers - Where louvers are used for temperature control, they are generally located on surfaces which are shaded from the sun. However, it is generally impossible to find surfaces which are always shaded on spin stabilized spacecraft. With solar influx on louvered skins, wide variations of effective solar absorptance with shutter and solar aspect angles can occur (see Figure 1). This is largely due to the cavity effect at small louver angles. This problem makes it difficult to design a system which will emit nearly linearly (see Figure 2) with shutter position, while subjected to non-linear solar heating. Most of these systems also require a high degree of conductive coupling between the electronic components and the radiating surfaces.

In addition, it is not entirely certain that louvers which are oriented parallel to the spin axis and which are located at the spacecraft periphery will not affect the spin rate when they open or close.

B. Internal Canister - The Telstar satellite employed a cylindrical canister in which the electronic components were housed. The sides were wrapped with super insulation and the ends were used as active control surfaces. By varying the positions of the end caps, the radiation exchange with the spacecraft skin could be

controlled. The ratio of the volume of the internal canister to the volume of the total spacecraft was relatively small so that the temperature of the internal canister was almost independent of temperature gradients along the skin of the spacecraft.

C. Internal Shutter - The Relay satellite employed an internally mounted rotary shutter which controlled the amount of heat radiated from the electronic components to the bottom surface of the spacecraft. The bottom surface was kept relatively cool by controlling the launchtime so that the spacecraft's spin axis remained nearly perpendicular with respect to the sun. The temperature sensor for controlling the shutter was located at the battery and thus responded to local rather than average spacecraft temperature changes.

D. Rotary Blades Mounted on Skin (Atlas Able) - Spacecraft internal temperatures can also be controlled through the use of rotary blades which alternately expose or cover different surface coatings. This system was first designed for an Altas-Able satellite but was never successfully flown because of launch vehicle failures. It employs a light weight blade, bearings, and a bimetallic sensor-actuator. It is sensitive to inertial and vibratory loads and its calibration is easily shifted through handling and repeated cycling. Of all of the systems which have been discussed, the rotary blade controller appears to be the most suitable for controlling temperatures of spin-stabilized, non-oriented, satellites.

IV. Why Goddard's Requirements for Active Control are Different from Those of Other Spacecraft

By and large, the Goddard in-house satellites are spin stabilized with solar influx impinging on all surfaces of the skin at some time during the spacecraft's lifetime. This precludes the use of any one surface that is always shaded for mounting a louvered or internal shutter system. The high packaging density of Goddard spacecraft prohibits the use of the internal radiative technique for an active control system. In addition, packaging methods presently employed at GSFC make it difficult to control heat flow by conduction. Electronic modules are sometimes stacked six to eight inches above heat dissipating surfaces, with poor conductive coupling between layers.

V. Work to Date on Active Controller at GSFC

Because of the previously mentioned limitations of louver, canister, and shutter designs when applied to Goddard satellite configurations, it was decided to investigate the characteristics of an improved version of the Rotary Blade Controller. A new system is being designed employing a bimetallic coil with a high spring constant and molydisulfide impregnated nylon thrust bearings inserted to give the assembly more axial stability under vibratory loads. Figure 3 shows the controller in its mounting fixture.

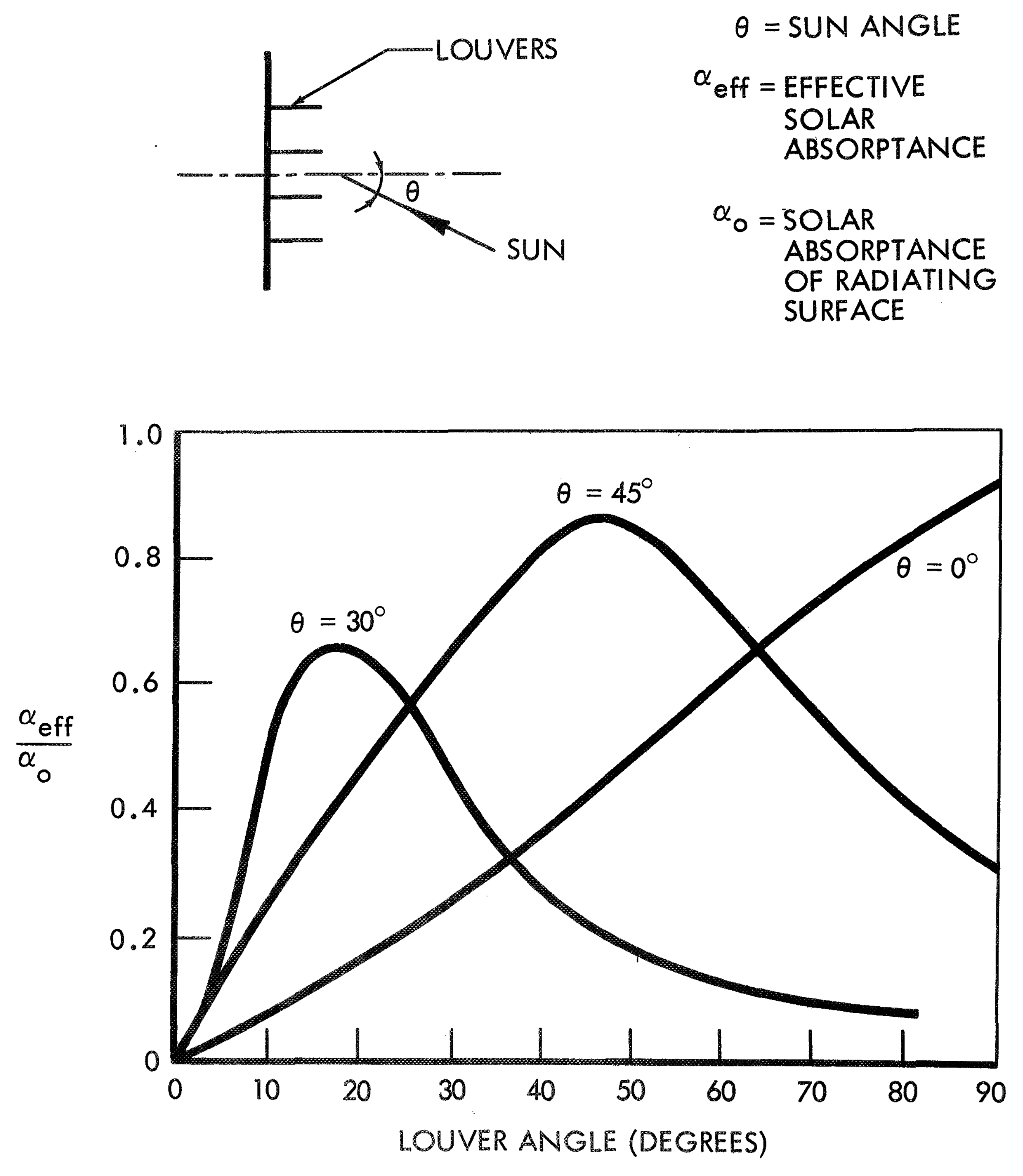

Figure 1. Effective Absorptance Vs. Louver Angle For Various Sun Agnles (θ)

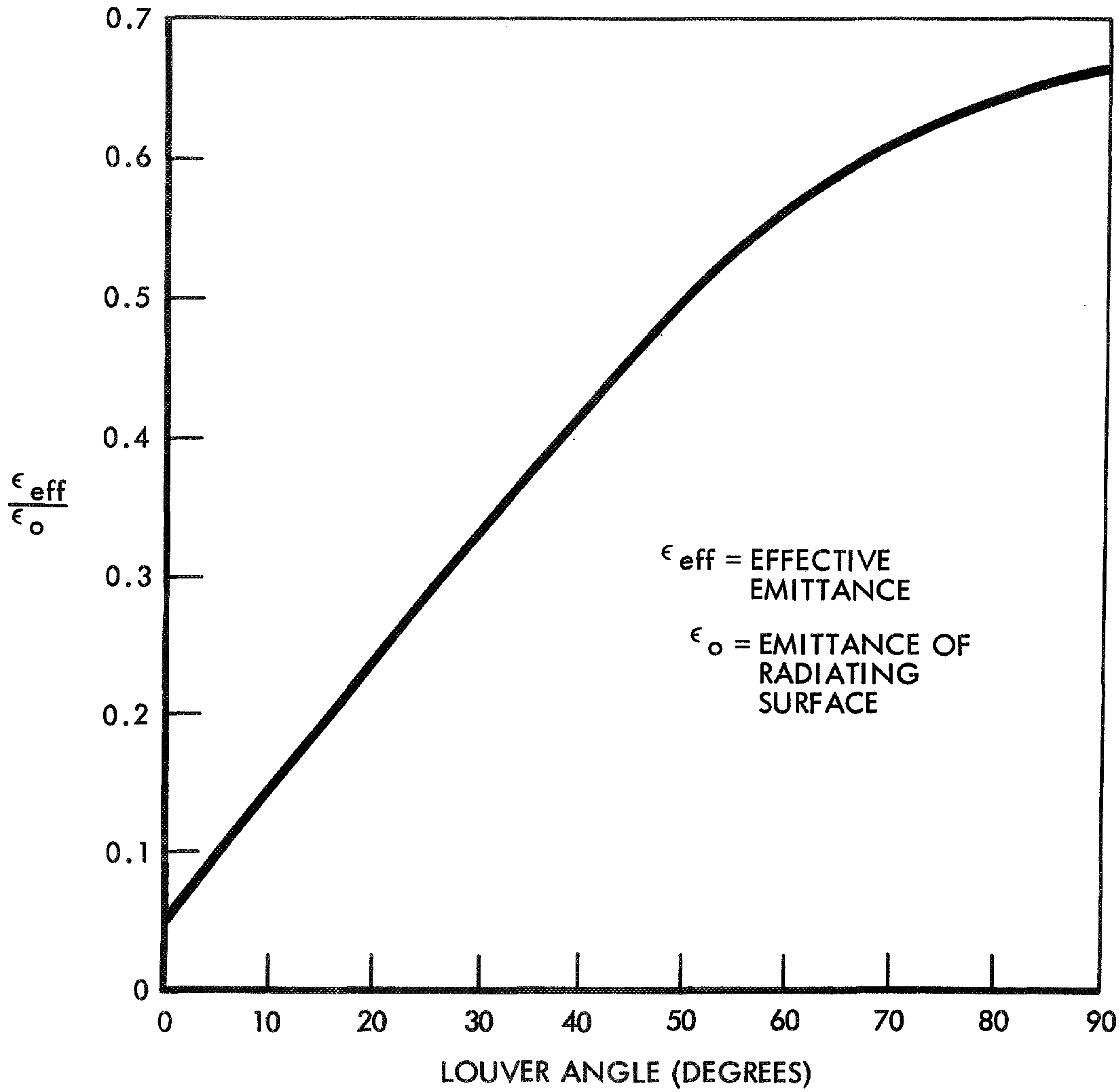

Figure 2. Effective Emittance Vs. Louver Angle

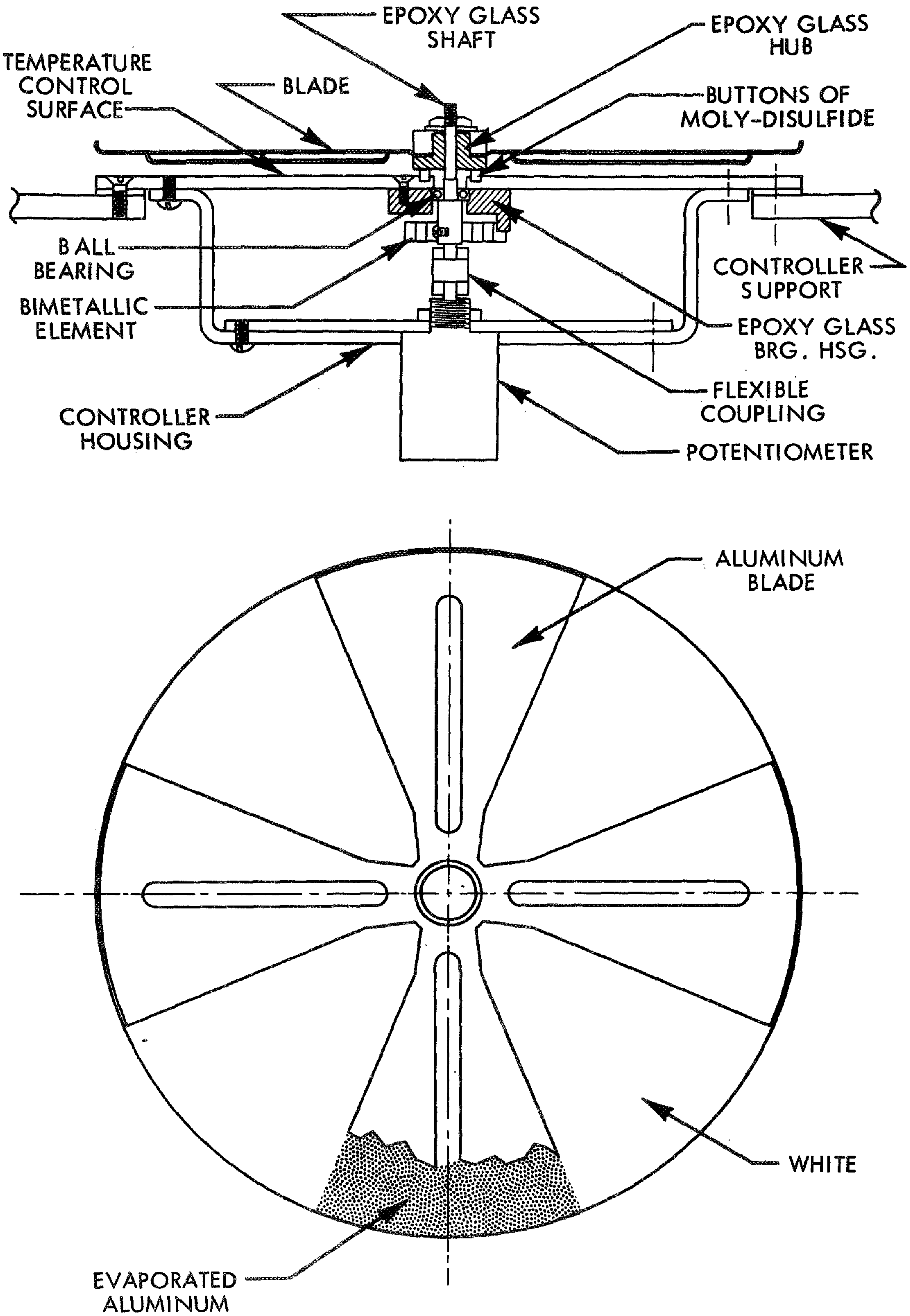

Figure 3. Active Temperature Control Assembly

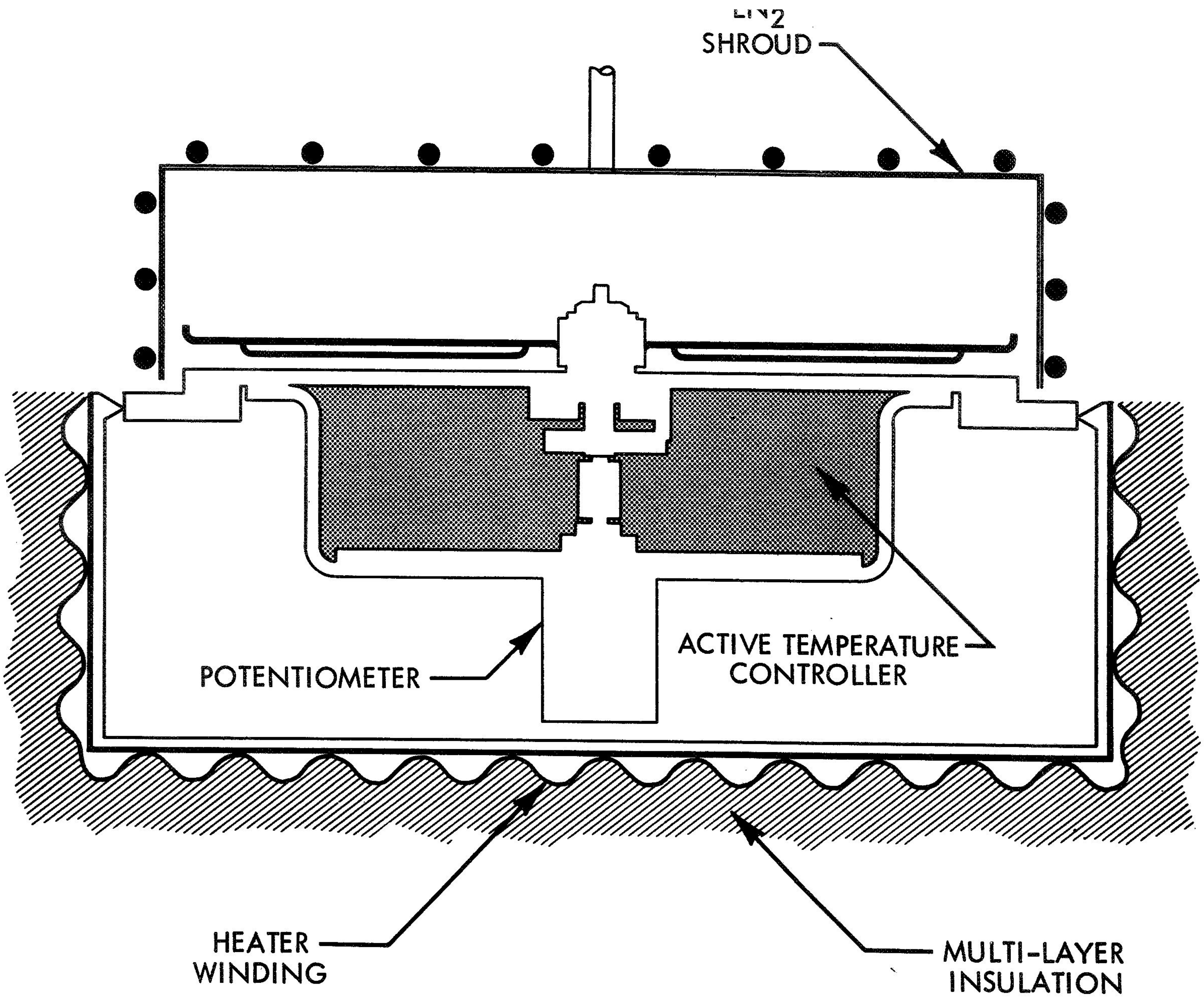

Figure 4. Assembly of Temperature Controller Into Test Fixture